



# LINEUP WITH MATH™

## Math-Based Decisions in Air Traffic Control for Grades 5 - 9

### Problem Set A

#### Introduction to Real Air Traffic Control

## Teacher Guide with Answer Sheets

### Overview of Problem Set A

In this Problem Set, students will be introduced to the key ideas, vocabulary, units, and graphical representations of air traffic control.

An introductory two-minute video, *What is LineUp With Math™?*, introduces students to the *LineUp With Math™* activities.

The heart of the Problem Set is a six-minute instructional video, *Welcome to Sector 33*.

Both videos are available on the *LineUp With Math™* website and can be projected for whole class viewing. Alternatively, students can access the videos from the ATC Simulator homepage and watch them on an individual computer monitor.

After viewing *Welcome to Sector 33*, students reinforce their understanding of the key concepts via the Problem Set A Student Workbook that provides a structured learning environment with paper-and-pencil worksheets.

### Objectives

Students will:

- Learn the vocabulary of air traffic control.
- Learn the units (nautical miles and knots) of air traffic control.
- Learn to read and interpret an airspace sector diagram.
- Learn the air traffic control spacing requirements for safety and efficiency.

### Prerequisites

None

### Materials

- Three Videos:
  - Animation of 24 hours of flight in the US
  - *What is LineUp With Math™*
  - *Welcome to Sector 33*
- Student Workbook A (print-based)

The materials are available on the *LineUp With Math™* website:

<http://www.smartskies.nasa.gov/lineup>



## Videos

All three videos are available for download on both the *LineUp With Math™* website and the Simulator website.

The first video, *Animation of 24 hours of flight in the US*, compresses 24 hours of flight paths to one minute. The video illustrates the world's biggest distance-rate-time-problem and motivates the study of air traffic control.

The second video, “*What is LineUp With Math™?*”, introduces students to the overall goals and activities, and features scenes of students engaged in *LineUp With Math™*.

The third video, “*Welcome to Sector 33*”, presents the vocabulary, units, and graphical representations used in air traffic control. It prepares students for their first session with the interactive ATC Simulator. It also prepares students for the activities in the first Student Workbook (Problem Set A).

## Student Workbook

*It is recommended that you have a copy of Workbook A open while you read these notes.*

The Workbook consists of two worksheets.

For each worksheet, the key points are briefly described as follows.

### **Worksheet: Introduction: Understand Real Air Traffic Control**

- Students may confuse “nautical miles” and “knots.” “Nautical miles” are a measure of distance; “knots” are a measure of speed (nautical miles per hour).
- Students may have difficulty reading a sector diagram to determine a plane’s exact starting distance from MOD. For example:
  - When the distance is not a multiple of five (e.g., for distances such as 28 Nmiles.).
  - When a plane passes through OAL on its way from LIDAT or MINAH.

### **Worksheet: Understand Aircraft Spacing Requirements**

- At MOD, air traffic controllers line up all Sector 33 planes to proceed to the next sector. Controllers aim for Ideal Spacing (3 Nmi) at MOD. Everywhere else, planes must have at least Minimum Separation (2 Nmi).

## Answer Sheets

Answer sheets for each worksheet in Student Workbook A can be found in Appendix I of this document.



## Math-Based Decisions in Air Traffic Control

### Student Workbook A

## Appendix I

- Introduction to Real Air Traffic Control
  - Units
  - Vector Display
    - Sector Information
    - Spacing Information

# Workbook Answers



Planes use nautical miles to measure distance and speed.

Investigator: \_\_\_\_\_

An Airspace Systems  
Program Product



## Understand Sector Information



Investigator: \_\_\_\_\_

### Understand Units

Distance:

Travel on land is measured in Statute Miles - commonly called "miles".

Travel in the air and on the sea is measured in **Nautical Miles (Nmiles)**.  
A nautical mile is a little *longer* than a statute mile.

$$1 \text{ nautical mile} = 1.15 \text{ statute miles}$$

A Nautical Mile is a little longer than a statute mile.



Speed:

Speed on land is measured in Miles per Hour (mph).

Speed in the air and on the sea is measured in Nautical Miles per Hour - commonly called "**knots**" (Kts).

$$1 \text{ "knot"} = 1 \text{ nautical mile per hour}$$

Just as a Nautical Mile is a little *longer* than a Statute Mile, 1 Knot (nautical mile per hour) is a little *faster* than 1 mile per hour.

### Understand the Sector Display

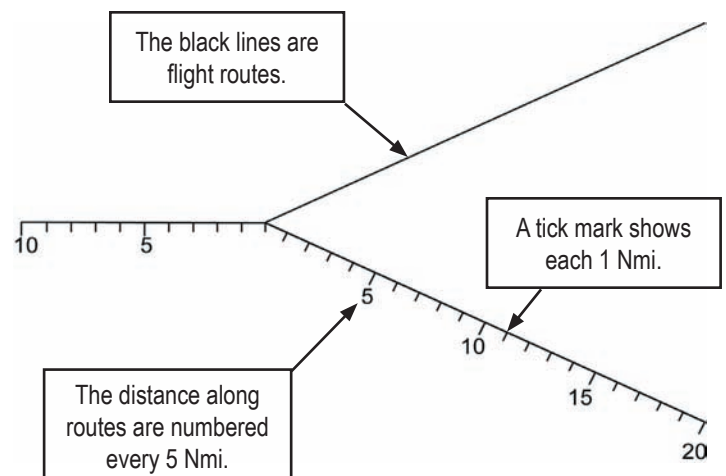
A **Sector** is the air space above a specific geographical section of the country.

Each sector has 2 air traffic controllers. They are responsible for the safe and efficient flight of all aircraft in that sector.

A sector is composed of many interconnected **Routes**. Routes are invisible pathways in the sky.

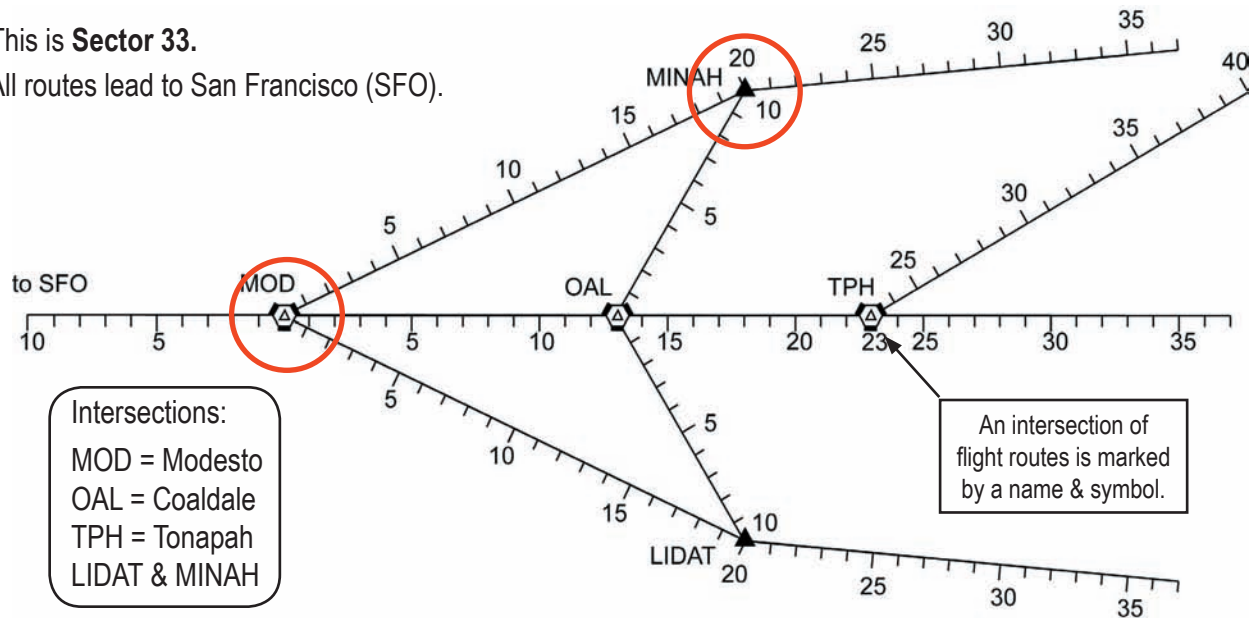
When you look at an air traffic problem display, you will see:

- > Lines to show the routes
- > Numbers at each 5 Nmiles distance
- > Tick marks at each 1 Nmiles distance



## Understand Sector Information (Continued)

- ✎ This is **Sector 33**.
- ✎ All routes lead to San Francisco (SFO).



- ✎ Sector 33 is a real sector in northern California. But we've used different distances.
- ✎ Sector 33 controllers merge traffic onto a single route at MOD.

It is important that you understand the distances between intersections.

1 Circle the intersections at MOD and MINAH.

2 What is the direct distance from:

	MINAH	TPH	LIDAT
To MOD?	<b>20</b> Nmi	<b>23</b> Nmi	<b>20</b> Nmi
To OAL?	<b>10</b> Nmi	<b>10</b> Nmi	<b>10</b> Nmi

Where is MOD?



3 How far is it from MINAH to OAL to MOD?

**23** nautical miles.

4 How far is it from MINAH to MOD directly?

**20** nautical miles.

5 How much shorter is it to go from MINAH to MOD directly rather than by way of OAL?

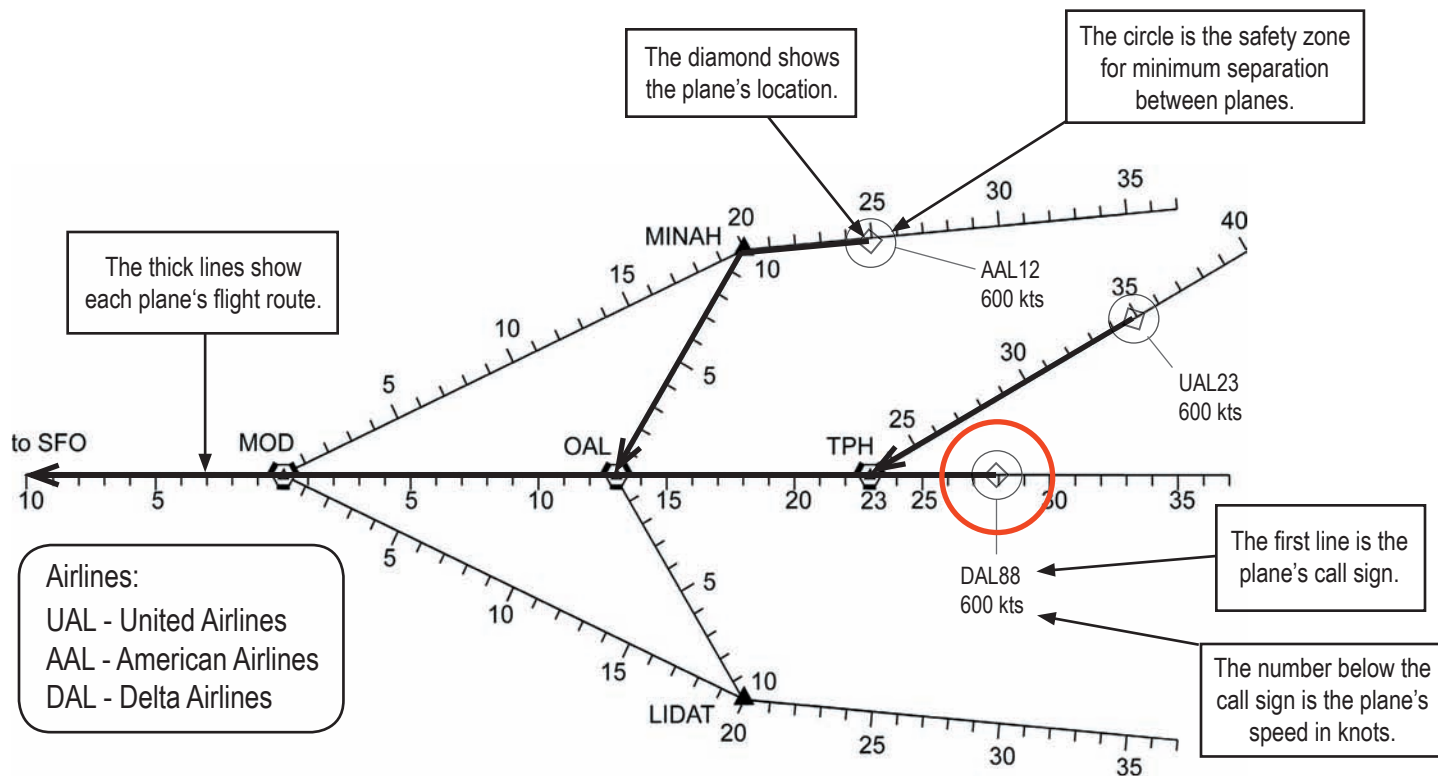
**3** nautical miles.

6 How much further is it to go from LIDAT to MOD by way of OAL rather than directly?

**3** nautical miles.

## Understand Sector Information (Continued)

Information for each plane, including its position, is shown on the sector display.



7

Circle the diamond for the Delta Airlines flight on the sector display.

8

What is the speed of the Delta Airlines flight? **600** knots.

A **Flight Plan** is a plane's route of travel from intersection to intersection, including speed (knots) and altitude. In our case, the altitude will be the same for all planes.

9

Locate flight AAL12 and write the intersections (in order) for its flight plan to San Francisco (SFO):

To: **MINAH** Then to: **OAL** Then to: **MOD**

10

What is the length of the flight route of AAL12 from its current position to MOD? **28** Nmiles  
 **$5 + 10 + 13 = 28$**

11

What is the length of the flight route of UAL23 from its current position to MOD? **35** Nmiles





# Understand Airplane Spacing Requirements



Investigator: \_\_\_\_\_



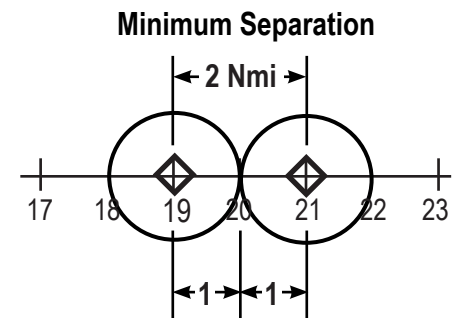
The **Objective** of air traffic control is to **safely** and **efficiently** move planes to their destinations.

## Safety - Minimum Separation

To be **safe**, planes must **always** be kept far enough apart that collisions and near-misses **NEVER** happen.

- ✎ The Federal Aviation Administration has established the least distance allowed between planes. This is called the **Minimum Separation**.

You will use **Minimum Separation = 2 Nmiles**



- ✎ On air traffic control displays, this minimum separation is shown by a “safety circle” around the plane symbol. The circle radius is 1 Nmile.
- ✎ When two circles just touch, the distance between the planes is 1 Nmi + 1 Nmi = 2 Nmi, the minimum separation.

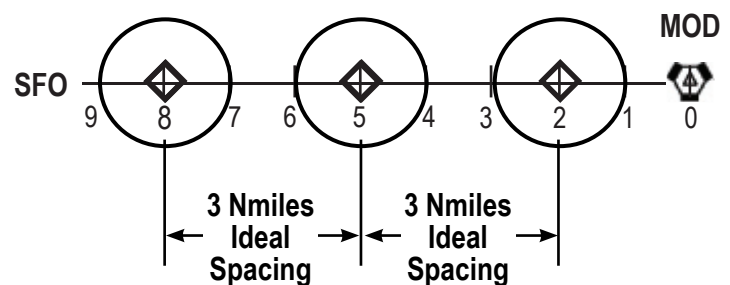
To be safe, the circles must **NEVER** overlap.



## Efficiency - Ideal Spacing

- ✎ At SFO, planes arrive from Sector 33 and from other sectors. So, at MOD the Sector 33 controllers must leave more than 2 Nmi to let planes from other sectors merge after MOD.
- ✎ This greater spacing is referred to as **Ideal Spacing**.

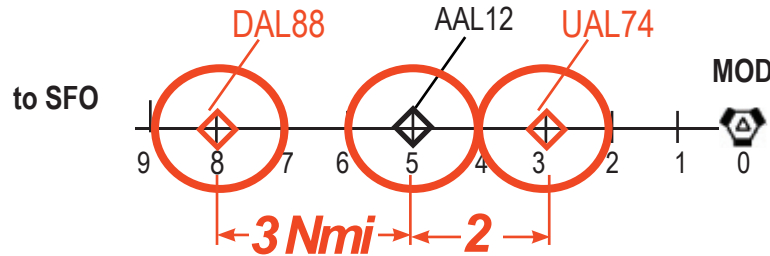
**Ideal Spacing at MOD = 3 Nmiles**



- ✎ You must aim for Ideal Spacing at MOD. Everywhere else you need at least Minimum Separation.

## Understand Airplane Spacing Requirements (Continued)

- 1 What is the Minimum Separation requirement? ☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5 Nmiles
- 2 What is the Ideal Spacing? ☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5 Nmiles
- 3 On the plot below, AAL12 is flying from MOD to SFO. Using the Minimum Separation, draw a "safety circle" around the flight symbol for this flight.



- 4 UAL74 is **following** AAL12 to SFO. On the route, draw a diamond to show UAL74 at the Minimum Separation.
- 5 Draw a "safety circle" around the diamond for UAL74.
- 6 DAL88 is **ahead** of AAL12 to SFO. On the route, draw a diamond and a safety circle to show DAL88 at the Ideal Spacing.
- 7 In each diagram, check all boxes that are **true**.

